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TESTING AND EVALUATION OF THE AVIONIC INSTRUMENTS INC. FREQUENCY CONVERTER

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AIR FORCE MATERIEL COMMAND
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ARMSTRONG LABORATORY

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This report has been reviewed and is approved for publication.

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HQ AMC/SGXR, being the lead agent responsible for procuring an interface device implementing compatibility of medical equipment using 115VAC/60 Hz single phase power to 115VAC/400 Hz three phase power, requested Aeromedical Research to evaluate converter devices that could fulfill this need. The Avionic Frequency Converter is an electronic device that converts aircraft 400 Hz, three phase, 115-200 Vrms into 60 Hz, single phase, 115 Vrms providing up to 3500 watts of power. Aeromedical Research staff members within the Systems Research Branch, considers the unit acceptable for use in the aeromedical evacuation environment.

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TSgt Allen Jones
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TESTING AND EVALUATION OF THE AVIONIC INSTRUMENTS, INC., FREQUENCY CONVERTER

BACKGROUND

The US Air Force has been designated the mission of providing aeromedical airlift support for Department of Defense personnel. Two aircraft, the C-130 and C-141, are primarily used for the transport of cargo, but may be configured for aeromedical use. Neither of these aircraft have the 110-120 volt alternating current (VAC) 60 Hertz (Hz) power required for most medical equipment items. Each of these aircraft has 115 VAC/400 Hz and 28 volt direct current (VDC) which, when connected by additional devices, can power medical equipment. For the 115 VAC/400 Hz current to be used, a frequency converter must be employed to step-down the frequency to 60 Hz. HQ Air Mobility Command (AMC) is presently looking for a frequency converter that will be lighter in weight and more effective than the one currently used. Avionic Instruments, Inc. requested we evaluate their frequency converter to determine its compatibility with aeromedical aircraft systems and the airborne environment.

DESCRIPTION

The Avionic Instruments, Inc. Frequency Converter Model 4B3500-1A is an electronic device that converts aircraft 400 Hz, three phase, 115-200 Vrms into 60 Hz, single phase, 115 Vrms. It employs patented circuitry and proven technology to provide up to 3500 watts of power. The efficiency of the unit is 80% or greater under normal operating conditions. The unit is designed to operate at 3500 watts fully loaded (115 volts @ power factor 0.8 leading to 0.75 lagging).

The Frequency Converter is designed to withstand extreme shock, vibration, acceleration, altitude, temperature, short circuit, and overload conditions without damage. The Frequency Converter's dimensions are:

Length	21 in. (includes handles and fan shroud)
Width	9 in.
Height	6 in.
Weight	45 lb.

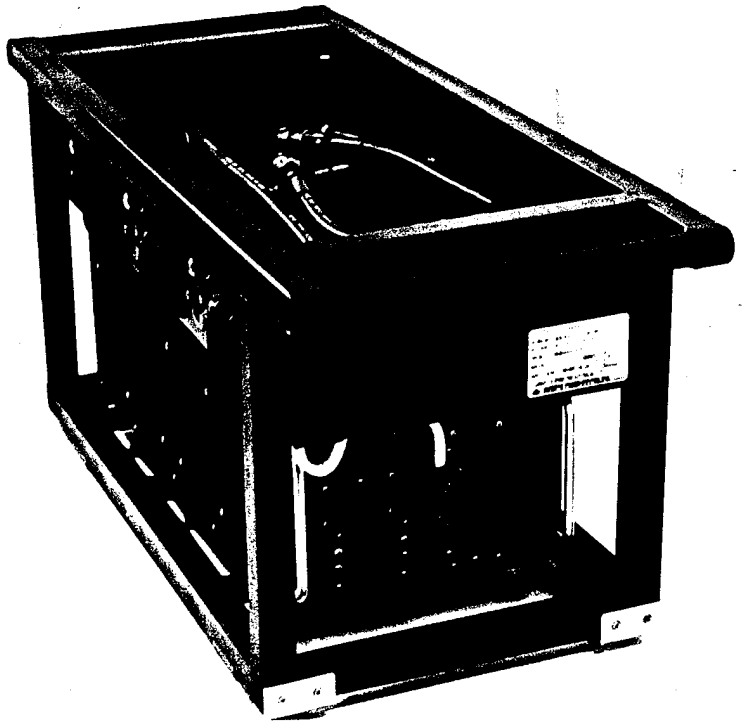


Figure 1. The Avionic Instruments Inc., Frequency Converter

PROCEDURES

Test methods and performance criteria were derived from various military standards (Reference List 1-2), nationally recognized performance guidelines (3), and manufacturer's literature (4). The Aeromedical Research Procedures Guide describes safety and human factor issues to be considered during equipment testing (5). A test setup and performance check were developed to verify proper functioning of the equipment under various conditions.

The device was subjected to various laboratory and inflight tests to observe and evaluate its performance under anticipated operational conditions.

1. Initial Inspection

2. Electrical Safety

3. Vibration

4. Electromagnetic Interference (EMI)

5. Environmental, encompassing:

    a. Hot Operation

    b. Cold Operation

    c. Humidity

    d. Hot Temperature Storage

    e. Cold Temperature Storage

6. Altitude

    a. Cabin Pressure/Altitude

    b. Rapid Decompression to Ambient

7. Airborne Feasibility

TEST SETUP

A test setup was assembled to enable evaluation of the Frequency Converter's function.

a. Test SetUp: The Frequency Converter's input cable was modified to mate with a standard four-prong, three-phase receptacle near Armstrong Laboratory's hypobaric chamber A5/6. Specially designed resistive loads, each with unique test ports for attaching measuring instrumentation, were inserted into receptacles on the

front of the Frequency Converter. A Hewlett Packard Model 54600B Oscilloscope was plugged into the test portals to measure the performance parameters outlined in the performance check and to monitor the apparent quality of the output waveform.

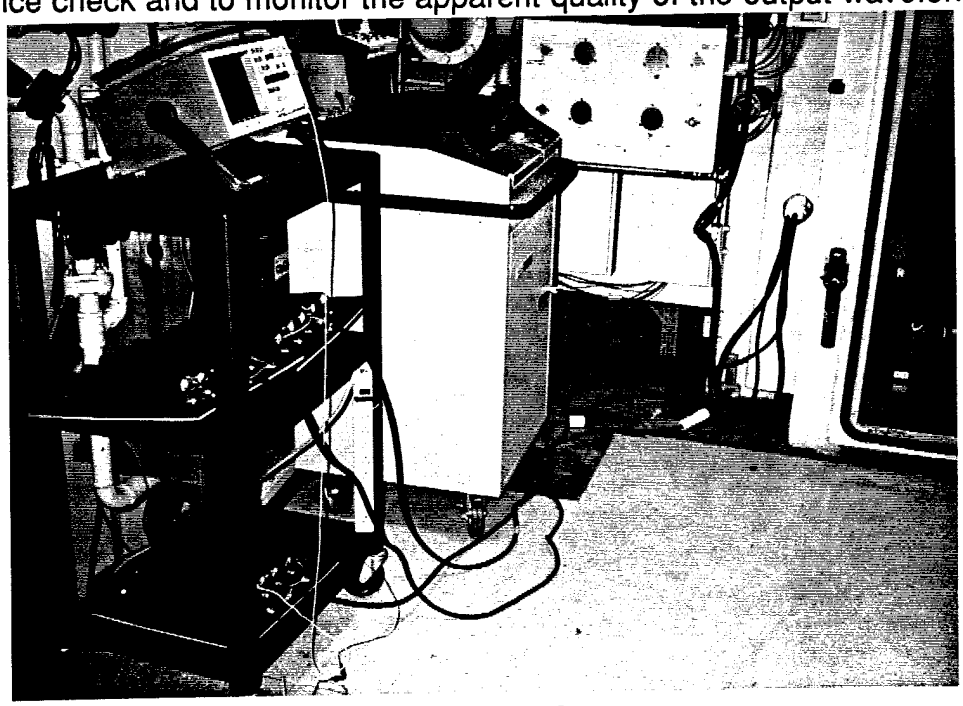


Figure 2. Test Setup

b. Performance Check: The laboratory's portable generator provided three-phase 115 VAC, 400 Hz power to the Frequency Converter. Resistive loads were then inserted into each receptacle while input/output voltage, duty cycle, frequency, and time were measured and recorded. This performance check validated that the generator functioned according to the manufacturer's specifications and served as a baseline for further laboratory testing.

INITIAL INSPECTION

a. The Frequency Converter was inspected for quality of workmanship, production techniques and possible damage incurred during shipment.

b. The Frequency Converter was checked to ensure it met safety requirements and operating characteristics established in National Fire Protection Agency (NFPA) 99 (6), Electrical Shock Hazards, AFI 41-203 (7), and Equipment Management in

Hospitals, AFI 41-201 (8). Ground resistance and leakage current measurements were made at 60 and 400 Hz.

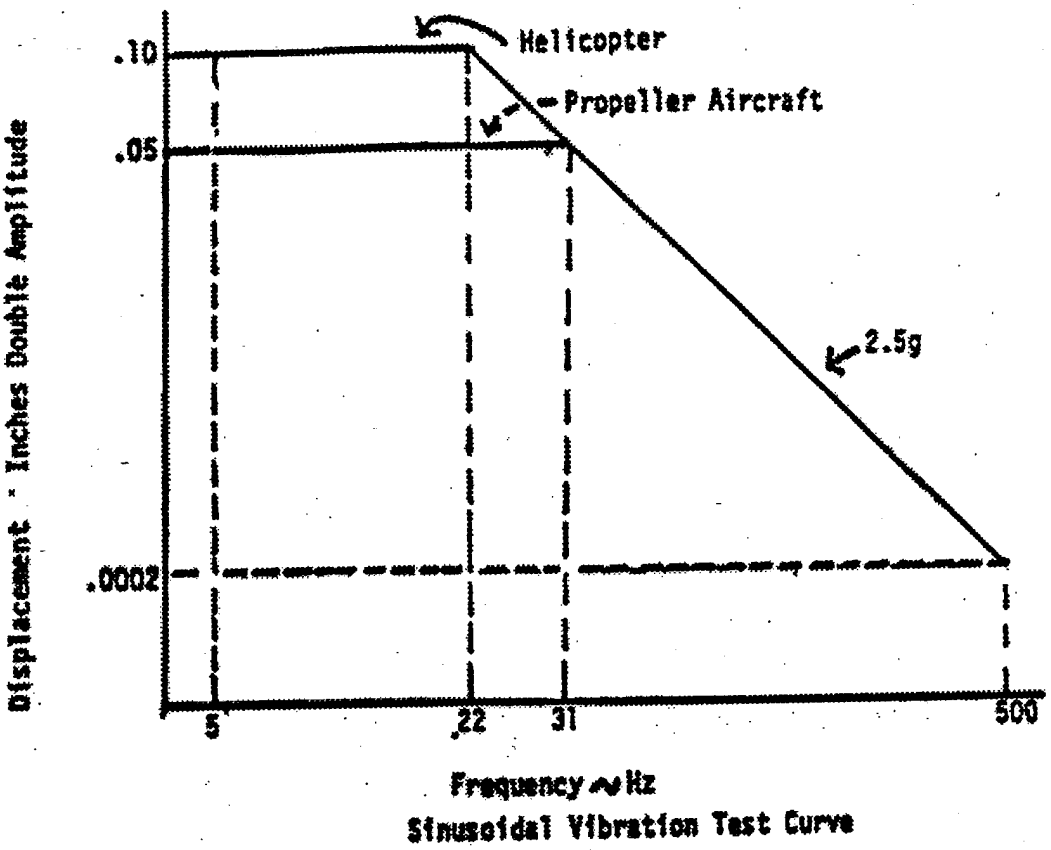
c. Operation and calibration procedures were verified in accordance with manufacturer specifications, and the performance check procedures described in the protocol developed by the Aeromedical Research staff (5).

ELECTRICAL SAFETY

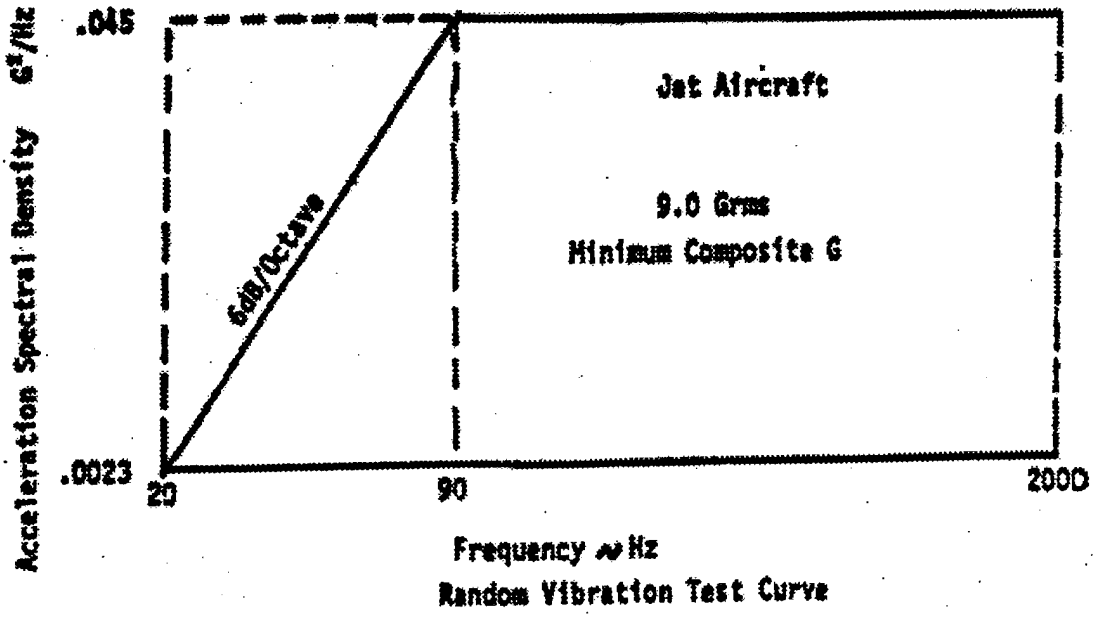
Biomedical Equipment Technicians and Aeromedical Research engineers performed this evaluation on the Frequency Converter to ensure the safety of both the equipment operator and the patient. This assessment involves measuring the equipment's leakage current and ground-to-chassis resistance as well as a general inspection of the device. The required limits are established in National Fire Protection Agency (NFPA) 99 (6), Electrical Shock Hazards AFI 41-203 (7), and Equipment Management in Hospitals AFI 41-201 (8).

VIBRATION

Vibration testing is critical to determine "the resistance of equipment to vibrational stresses expected in its shipment and application environments" (2). Vibration testing was conducted at Avionic Instrument's vibration facility. This testing involved a set of operational tests performed along each of the Frequency Converter's three axes - X, Y, and Z, with the Frequency Converter mounted on the shaker head. It was subjected to vibration curves with levels and lengths from those depicted in Category 10, Figures 514.4-16 and 514.4-17 of MIL-STD-810E (Figures 3 and 4).



Sinusoidal Vibration Test Curve



Random Vibration Test Curve

Figures 3 & 4. Vibration Test Curves

ELECTROMAGNETIC INTERFERENCE

Electromagnetic compatibility testing is a primary concern on USAF aeromedical evacuation aircraft. Ensuring the safety of everyone on board is the driving factor to accessing the effects of excessive electromagnetic emissions and their influence on aircraft navigation and communication equipment. Additionally, medical devices may be susceptible to fields generated by the aircraft equipment or other medical devices and malfunction in their presence.

The Frequency Converter was evaluated for compliance with MIL-STD-461D (1). WL/AAWA-2, Wright-Patterson AFB, performed the evaluation in their electromagnetic compatibility facility. ASC/ENAI evaluated the electromagnetic compatibility data and determined the airworthiness of the medical device. Specific tests conducted were as follows:

a. Radiated Emissions (RE-102), " Radiated Emissions, Electric Field, 10 kHz to 18 GHz.": For Air Force aircraft applications, radiated emissions are tested in a narrower range of frequencies from 2 MHz - 1 GHz. This test determined the amount of EMI emitted by the equipment during its operation. This test must be performed to ensure that the device does not affect other pieces of equipment that may be susceptible to electromagnetic emissions (i.e., aircraft navigation and communication equipment).

b. Conducted Emissions (CE-102), " Conducted Emissions, Power Leads, 10 kHz to 10 MHz.": For Air Force aircraft applications, conducted emissions are tested throughout the entire band of 10 kHz - 10 MHz. This test measured emissions generated by the medical device along its power supply lines. This test must be performed to ensure that operating the device using line power does not affect other items connected to the same power source, particularly aircraft systems.

c. Radiated Susceptibility (RS-103), "Radiated Susceptibility, Electric Field, 10 kHz to 40 GHz.": For Air Force aircraft applications, radiated susceptibility is tested in a narrower frequency range from 30 MHz - 12.4 GHz at the following field strength levels: 20 V/M below 1 GHz and 60 V/M above 1 GHz (field strength values from Table IV, category Aircraft Internal, of 461D). This test determined whether or not

the device would withstand pre-defined levels of EMI generated by antennas both internal and external to the aircraft.

d. Conducted Susceptibility (CS-101), "Conducted Susceptibility, Power Leads, 30 Hz to 50 kHz.": For Air Force aeromedical aircraft applications, conducted susceptibility is tested throughout the entire frequency band, from 30 Hz to 50 kHz. This test determined whether the components would "withstand ripple voltages associated with allowable distortion of power source voltage wave forms."

e. Conducted Susceptibility (CS-114), "Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 400 MHz.": For Air Force aeromedical aircraft applications conducted susceptibility is tested throughout a narrower portion of the frequency band, from 10 kHz to 200 MHz. This test was performed to determine whether "simulated currents that will be developed on platform cabling from electromagnetic fields generated by antenna transmission would affect the equipment under test."

f. Conducted Susceptibility (CS-115), "Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation": This test was performed to ensure the Frequency Converter could withstand the "fast rise and fall time that may be present due to platform switching operations and external transient environments such as lightning and electromagnetic pulse."

ENVIRONMENTAL

Extreme temperature and humidity testing is critical to determine if aeromedical equipment can be stored and operated under severe environmental conditions "without experiencing physical damage or deterioration in performance." (2) Extreme environmental conditions can have numerous incapacitating effects on medical equipment including, but not limited to, the following: changes in material characteristics and material dimensions, possible overheating, changes in lubricant viscosity, changes in electronic components, and electronic or mechanical failures due to rapid water or frost formation.

Testing was conducted in the Kelly AFB Environmental Systems Chamber Model TAH/15 operated by Kelly AFB technicians and monitored by personnel

assigned to the Systems Research Branch (CFTS) of the Crew Technology Division at Armstrong Laboratory, Brooks AFB, TX. The Frequency Converter was placed in the center of the environmental chamber. All input and output cables and wires were routed through a port in the chamber wall, which was subsequently sealed with a precut sponge plug. The other components of the test setup were outside the chamber. For operational tests, the Frequency Converter was monitored continuously, and a performance check was conducted every fifteen minutes. For storage tests, the Frequency Converter was placed in the chamber and remained nonoperational throughout the storage portion of the test. The following describe the conditions of the environmental tests performed:

a. Humidity: 94 ± 4% RH, 85°F ± 3.6°F (29.5°C ± 2°C) for 4 hrs

b. Hot Temp Operation: 120°F ± 3.6°F (49°C ± 2°C) for 2 hrs

c. Cold Temp Operation: 32°F ± 7.2 (0°C ± 4° C) for 2 hrs

d. Hot Temp Storage: 140°F ± 3.6°F (60°C ± 2°C) for 6 hrs

e. Cold Temp Storage: -40°F ± 3.6°F (-40°C ± 2°C) for 6 hrs

ALTITUDE

Testing was conducted in the Armstrong Laboratory research chambers operated and monitored by chamber operation personnel assigned to the Systems Research Branch (CFTS) of the Crew Technology Division at Armstrong Laboratory, Brooks AFB, TX.

a. Cabin Pressure/Altitude: Altitude testing is critical for aeromedical evacuation equipment due to the potential effects of barometric pressure changes on the equipment. A majority of the aircraft, which are characterized as opportune aircraft available for use in aeromedical evacuation, pressurize their cabin atmosphere to barometric pressures equivalent to 8,000-10,000 feet above sea level. The differences in pressures can be critical to the effective operation of some medical equipment. Altitude testing consisted of operating the Frequency Converter while

ascending from ground level to 10,000 ft (maintaining altitude for one hour) and then descending back to ground, at rates of 5000 ft/min, while stopping at 2000 ft increments to allow for performance checks.

b. Rapid Decompression Testing: Rapid decompressions are caused by the loss of aircraft cabin pressurization and subsequent pressure equalization with ambient atmospheric pressure. It is important to determine how medical equipment will function during and after such a decompression and ensure that it will not endanger a patient, the aircraft personnel, or the aircraft itself. The Frequency Converter operated inside the rapid decompression test chamber as the chamber was pressurized to an equivalent of 8,000 ft (2,438 meters) altitude. Then, the chamber altitude was brought to 40,000 ft (12,192 meters) over a period of 60 seconds, held at 40,000 ft briefly, and then brought back down to ground at a rate of 10,000-12,000 ft/min. The test was repeated twice with the decompressions occurring over seven and one seconds, respectively. The Frequency Converter was monitored throughout the series of decompressions, to include performance checks each time the unit returned to ground level. The load resistors and monitoring equipment remained outside the chamber. Connectors joining the monitoring equipment and the Frequency Converter were run through putty-sealed access ports in the chamber walls.

AIRBORNE FEASIBILITY

Airborne feasibility evaluations are a cost-effective and invaluable means of validating a piece of equipment's clinical and operational suitability under actual operating conditions. By carefully evaluating medical equipment items in their actual environment, Aeromedical Research ensures that all pertinent patient care issues are adequately addressed by the test protocols. Ensuring safe and effective operation of this medical equipment support device is the primary goal of the inflight evaluation and forms the basis for subsequent recommendations to the users.

This phase of inflight testing was conducted by an aircraft-qualified aeromedical research technician, aboard a C-141 aeromedical evacuation training mission out of Kelly AFB, TX. The Frequency Converter was secured to the floor of the aircraft using cargo tie-down straps and "D" rings and evaluated throughout the flights by Aeromedical Research technicians as well as the other members of the aeromedical

evacuation crew. An assortment of medical instrumentation was operated from the Frequency Converter. The capability to support this instrumentation as well as human factors characteristics, securing methods, and equipment setup times and locations were evaluated.

RESULTS

INITIAL INSPECTION

Initial inspection results revealed no manufacturing defects. The unit performed to the manufacturer's specification.

ELECTRICAL SAFETY

All parameters were within referenced guideline limits.

ELECTROMAGNETIC INTERFERENCE

The Avionic Instruments, Inc., Frequency Converter passed all phases of EMI testing and was found to be acceptable for use in the aeromedical evacuation environment.

VIBRATION

Vibration testing was performed by Avionic Instruments, Inc. personnel. Reported data were reviewed and accepted by Aeromedical Research engineers as meeting airworthy standards of operation.

ENVIRONMENTAL

The Frequency Converter operated satisfactorily during all five phases of testing. The unit underwent Hot Storage & Operation and Cold Storage & Operation at a Kelly AFB, TX facility under Aeromedical Research supervision. Humidity testing was accomplished at Armstrong Laboratory, Brooks AFB, TX complex by Aeromedical Research staff.

ALTITUDE

1. Cabin Pressure/Altitude: The Frequency Converter performed in accordance with manufacturer's specifications throughout testing.

2. Rapid Decompression: The Frequency Converter operated satisfactorily following each decompression.

AIRBORNE FEASIBILITY

This evaluation confirmed that the Frequency Converter will successfully function on the C-141 aircraft during all phases of flight. Analysis of human factors data indicates this unit was easy to enplane and deplane, compatible with aircraft electrical systems, and easily integrated with various types of medical instrumentation routinely used on aerovac missions.

RECOMMENDATIONS

We recommend installing wheels on the base of the converter that would make it possible for one person to enplane the unit.

CONCLUSIONS

Overall, the Frequency Converter is considered airworthy. It proved to be extremely easy to setup and operate and met all of the standards and limits outlined in our references for testing aeromedical evacuation equipment. The Frequency Converter operated within expected parameters when subjected to environmental extremes and simulated cabin altitudes. We feel it will make a significant contribution to the aeromedical evacuation mission.

REFERENCES

1. MIL-STD 461D, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, Category A1e.

2. MIL-STD 810E, Environmental Test Methods and Engineering Guidelines.

3. Emergency Care Research Institute (ECRI), INDEX 1993

4. Frequency Converter, Model 4B3500-1A, Installation Manual.

5. Aeromedical Research Procedures Guide, Internal Operating Instruction, Systems Research Branch, Armstrong Laboratory.

6. National Fire Protection Agency (NFPA) 99, Health Care Facilities Code

7. AFI 41-203, Electrical Shock Hazards

8. AFI 41-201, Equipment Management in Hospitals

APPENDIX A

APPENDIX
MANUFACTURERS SPECIFICATIONS OF THE AVIONIC INSTRUMENTS INC. 4B3500-1A FREQUENCY CONVERTER

ENVIRONMENTAL	
Temperature	-55° to 71° C
Altitude	50,000 feet
Cooling	Fan Cooling
INPUT POWER	Three-phase, 400 Hz 115/200 Vrms
OUTPUT POWER	115 Vrms, 60 Hz, 3500 VA
POWER FACTOR	0.75 lagging to 0.8 leading
DISTORTION	2.5% THD Max - Normal Conditions. 1% Typical
EFFICIENCY	80%, Min - Normal Operating Conditions. 85%, Min - Normal Input, Full Rated Load
FREQUENCY REGULATION	60 ± 0.7 HZ - Normal Input Voltage, Load and Temperature. 60 ± 2 HZ - Transient Conditions
VOLTAGE REGULATION	115 ± 3.0 Vrms - No Load to 100% Load. 115 ± 20.7 Vrms- Transient Conditions

OVERLOAD CAPABILITY	4300 Watts for five minutes without damage at nominal input voltage. Output voltage remains 112 to 118 Vrms.